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## The External and Internal Structure of Formosa.

The structure of Formosa has become known in its fundamental aspects. Until a short time ago, the knowledge was confined to limited information from peripheral points, especially from Takao in the southwest and Kilung and Tamsui in the extreme north. More detailed studies were begun by the Japanese after their occupation of the island. But they, too, encountered difficulties in their research due to the [965] hostility of the wild tribes in the mountains of the inland region and the eastern part and therefore detailed information is yet lacking on some points of importance.

The cartographical representation of the inland parts of the island is still quite incomplete. The coastal regions have been charted long ago on the maps of the British Admiralty. Besides, their flat character in the west was known and their steep topography in the east. Furthermore no one who has sailed along the east coast in clear weather has failed to realize the impressiveness of the rugged forms of the coastal line and the mountains visible behind them. Some of the highest peaks of these mountains were determined in their approximate height from the sea; the most important names are Mt. Sylvia and Mt. Morrison. These mountains are part of the mountain chain projected in an easterly direction and following the longitudinal direction of the island; from it lesser mountain ridges slope down to the low-lying west. That is the picture that until a short time ago found its expression on the available maps.

On the whole this picture has been proved correct by the Japanese explorations, as far as they go. But many detailed particulars have become known by a study of the geologic structure.

External Structure: One of the most important discoveries was that of the strange Taito trough, which sharply delimits the continuous massive of the older mountains on the east side along a completely straight line 155 kilometers long and oriented N 20° E. It is important to realize that it belongs to three river systems separated from one another by low passes (approximately 200 meters in height); two of the rivers pour out their waters at the two exits of the trough, whereas the third takes its way through the Taito mountain chain into which it has cut its narrow valley. This Taito chain is projected towards the east; it is 130 kilometers long and no more than 13 kilometers wide and reaches a maximum height of 1550 meters. It dates from the Tertiary Age and rises as a strange formation next to the old ridge. The settlements of Karenko (24° N) and Pinan (22° 45' N) mark the ends of this projected coastal mountain range. [966]

Between the Taito trough and a line west of it at a distance of fifty kilometers or more in some spots, which has approximately the same orientation, there rises the great mountain chain with its high crests which Ischii has called the Taiwan Mountains. The two dominant peaks, the Setsu-san (Mt. Sylvia, 3424 meters) and the Niitaka (Mt. Morrison, 4145 meters), are located on a line that also strikes N 20° E and passes through

the Kantaban peak (height, 3017 meters). Westward there follow Tertiary mountains. Here again, the orientation N 20° E is observed in the mountain range which Yamasaki calls the Kali chain; it does not serve as a watershed, but instead several rivers of the western slope of the Taiwan Mountains flow through it on their way to the coast.

The line of strike, mentioned N 20° E, is a basic feature of the structure of the Taiwan Mountains. This becomes even more obvious if we consider a factor which is always important for the judgment of mountain formations, namely the character of the small headwaters. Yamasaki has shown himself most conscientious in the charting on his map; the streams that have been definitely traced in their courses are carefully differentiated from those that have not been explored in all detail. It is easy to see that the valleys in the mountains, in so far as they adhere to a longitudinal orientation, strike N 15°-20° E; besides, a feature characteristic of the parallel structure may be observed, namely the connection by short transverse streams. This is very clearly shown by the main river of the island, the Dakusui-kei which crosses the connecting line between the two main peaks and takes its origin from headwaters which flow to both sides of this line in longitudinal valleys. A similar arrangement is found also within the Tertiary Mts. projected towards the west.

South of the Setsu-an, then, in the main section of the mountains, the orographical elements reveal the existence of a parallel structure. The total setup of the mountains, however, deviates, for the main watershed that connects the two principal peaks does

not follow the mentioned direction of strike, but extends in a slight arc, concave towards the west. This eastern regression, which in part obscures the parallel arrangement should probably be explained by the greater amount of precipitation on the west side. For at the time of the summer monsoon, southerly winds prevail whereas in the winter they are northerly and northnorth-easterly. It ought to be added [967] that even in case of equal amounts of precipitation on both sides, the more solid rocks of the east side would offer more resistance to the regression of erosion towards the west than the more destructible rocks of the west side would be able to muster in the easterly direction.

The northern part of the island differs from the structure just described. An east to west watershed extends under 24° 30' N from the promontory of Dom-kaku at the eastern coast by way of the Setsu, which it leaves slightly to the south, to the Kali-san. As far as they are known, the rivers of the northern side flow radially in relation to it, and their beds through the mountains which soon decrease very definitely in their elevation. This area is divided into strips, again arranged radially, all through the action of the streams.

In the attempt to construct the orographical main line of Formosa, either the high rib extending from the Setsu eastward to Dom-kaku has been taken as a starting point or the lower rib running northeastward and ending in Cape Santiau (the Sanschō-kaku of the Japanese). To it the cuspate watershed mentioned was added from the Setsu to the

Niitaka; from the latter mountain, the line was continued along the watershed, first S 20° W to the Nantaibu and from there meridionally to the southernmost promontory. Thus the idea of a mountain curve convex towards the west and slightly concave towards the east could develop.

Naturally the character of the divide line cannot be a decisive factor in a consideration of the morphology of the old mountain formations of Formosa because it has definitely been subject to erosive activity.

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Internal Structure of the Older Mountains. Japanese geologists have determined definitely that the fundamental formation of the Taiwan Mts. is distinguished in its structure from the outer and later parts. In the east it ends almost abruptly at the straight line of the Taitō valley. If this line is continued beyond the two ends of the valley, it marks the approximate extent of the other parts of the eastern coast. Only in the north are two promontories slightly projected beyond it. Passing over more than two degrees of latitude from Paroye (22° 22') to Soō (24° 36') it marks the sharply defined eastern slope of the older mountains. Observations were made around Soō. The coastal strip with a length of 50 kilometers that extends from there to Schiyō by way of Cape Dom-kaku seems to be completely unexplored. It is renowned for its high and precipitous rocky descents that have an altitude of more than 1000 meters. Otherwise studies have been made of the entire line. [968]

The most valuable clue as to composition is found in a transverse member of the mountains which Ischii has charted between 23° 35' and 23° 48'. It starts at Bassi-schō in the Taitō valley and runs westward across the Bun-sui-rei pass that has an altitude of 3240 meters. But even previously, at an elevation of 3150 meters, the impressive ridge of the eastern side is reached; it stretches in great length and is formed by a thick layer of white crystalline limestone. Ischii started his observations at the foot and noticed a continuous western dip and mighty strata of sericite schists, graphitic-chloritic

chists, and chlorite schist (enumeration from the foot up). He calls this system of ayers "crystalline schists" and puts it in parallel with some of the Archeozoic formations f southern Japan. Then follows the crystalline limestone and, above it, argillaceous chist in which the pass is found. Ischii assumes that these two formations date from he Paleozoic. Others are inclined to think of the limestone as belonging to the Archeo-oic and the argillaceous schist as dating from the Paleozoic. No traces of fossils have ver been found. Argillaceous schist prevails completely in the entire western part of he section.

When we consider the mentioned formations of the strike we find that the crystalline chists constitute a continuous zone along the eastern slope of the mountains and strike arallel to it, or N 20° E. Northward they continue as far as the eastern mountains are nown, i. e., as far as Schiyō and southward close to Pinan. But in the latter case a uzzling strip of argillaceous schist with a steep eastern dip (70-80°) is found adjoining. outh of Pinan the only rock formations investigated have been argillaceous schist. 'amasaki crossed several promontories of this type at the east coast.

Ischii claims that the argillaceous schist of the mountain heights describes first an nticline and later on a syncline. Over great distances the mountains are composed of his rock. The high peak of the Niitake (1) is made from it and southward it is known as

1. In 1896 Lieutenant Saitō and Dr. Honda climbed this mountain. They

brought back some rock specimens which Yamasaki identified as argillaceous schist. But Ischii found diorite in the environment of the mountain and granite close to Mt. Setsu, so that it is possible that the peaks may bear a definite relation to the occurrence of the eruptive rocks.

far as the parallel of Horyō (22° 22' N).

The results of later investigations are available concerning the composition and age of the "argillaceous schist formation." According to reports in Geology of Japan, the lowest rock materials are phyllite, quartzite, metamorphic [969] sandstone and crystalline limestone and the thick strata of argillaceous schists are not found until the very top. Higher up, sandstone intercalations are found in it and in the report the possibility is weighed that these upper formations may be Mesozoic. The difficulties of differentiating them accurately from the Tertiary are stressed.

In so far as the strike of the layers in the Taiwan mountains have been investigated and reported, they confirm the agreement with the strike assumed for the outer part of the mountains in the central and southern parts of the island. Some deviation in direction is found in the north. For the great precipitous descents at the Cape Domkaku, in spite of the fact that the line of descent is parallel to the direction of strike mentioned, have been

recognized as a transverse disruption of the strata which make up the mountain section that ends in them; this is a feature that very clearly distinguishes them from the slopes leading down to the Taito valley. Studies, however, seem to have been confined to the northern part of the mountains in the region of the triangular coastal plain of Giran. Here, near the small anchor bay of Soō, the strike of the layers is ENE-WSW whereas in the Geology of Japan, which was published later, it is E-W, with northerly folds. Yoschiwara has also visited the spot. In addition to the schists, he observed pyroxenite formations of the type characteristic of the lowest part of the Paleozoic Chichibu layers in Japan. In addition he claims that from here on everywhere in northern Formosa the direction of the strike is east to west.

The study of the deviating structure of the mountain section that ends with the Domkaku contributed a good deal to the assumption of a curved mountain chain concave towards the east. For the opinion now was that the mountains strike WSW around Soō, that there was a turn to the SW farther west, and that at the Setsu there was another change to the approximately meridional orientation of the watershed. The location of the Setsu, however, (W 10° S of Soō and at a distance of 55 kilometers from it) is not in agreement with this assumption, although it can easily be brought in line with the later ideas of an east-western strike. Then we are justified in the thought that we are here dealing with mountains of a structure different from that of the Taiwan Mts., that they [970] strike westward past the Setsu and that they may be interpreted as a

continuation of the Ryukyu curve.

The basic ideas are vital for a definite answer to the question and important for the morphological interpretation. But the regions beyond the borders of the Giran plain and the transitional zone from here to Kilung are inaccessible due to the fact that the land is inhabited by aboriginal tribes, therefore information is lacking. In so far as anything is known, the factors are not in favor of the assumed turn, but rather support the idea of a meeting of two different mountain curves that are harmonically in line with the structure of eastern Asia. A substantiation for this argument can be found in the fact that in the fundamental structure of the meridional mountains, the dip is exclusively to the west whereas in the case of the equatorial mountains it is always towards the north. In the mountain curve that is concave towards the east, we would have to expect the directly opposite dip in both instances.

Towards the north, the width of the equatorial mountain section seems to be slight. Ischii thought that the argillaceous schists extend northward as far as Tōi and that formations of this rock material found in the latter place date from the Mesozoic.(1) Yoschiwara

1. Tōi is located twelve kilometers north of Giran.

discovered Tertiary fossils in them, however. According to his own studies, the boundary between the Tertiary and the older schists lies south of Giran. In his opinion

the Tertiary takes the form of steep folds oriented east to west and accordingly the parts of the island north of about 24° 40' would belong to the Tertiary.

The younger encrustations: As far as we know, the older mountains constitute a ridge approximately fifty kilometers in width, narrowing somewhat in the southern part and oriented from S 20° W to N 20° E; in the north a transverse unit is added in a manner which cannot be clearly analysed. The continuous mass is encased in a mantle of younger formations that have been attributed to the Miocene and are interrupted only at some points of the eastern side. The younger strata have been disturbed and in the direction of the coasts they are in part hidden by later formations. In the northwest and in the Taitō chain they show intrusion or displacement by volcanic rock materials.

The pure Tertiary is confined to the Taitō chain, the mountain ridge that has previously been mentioned as having a length of 130 kilometers, and a width of no more than 13 kilometers, and as rising to a maximum elevation of 1550 meters between the Taitō [971] valley and the sea. It is said to consist of rocks dating from the Neogene. Sandy and clayey layers are followed by some of gravel; above them, in turn, appear volcanic tuffs and conglomerates; the peaks are of an andesite and are probably the remnants of old volcanoes. In various places incalcations of coral limestone point towards coastal formations. Above the present beach where corals are still found, Yamasaki observed three beach terraces. Together they have a width of 100-300 meters and it is here that the few human settlements of this area are found. Yamasaki also observed a coral reef fifty

meters above the sea.

In the narrow southern spur of the island which the Japanese call the Koschun peninsula, the Tertiary is represented by clastic rocks of lesser steepness. The maximum altitude is 1224 meters. Independent and apparently superimposed at a later time are coral reefs which constitute rugged hills up to 296 meters in height, and the two southern foothills.

The Tertiary is developed best on the west side of the island. The long twin rivers at first flow parallel to one another S 20° W, and later join and continue as the Tamsui-kei in the south: they have cut their beds into Tertiary mountains that in some places exceed 1300 meters in height. In its continuation, the northern half of the island contains the Kali mountain chain; it is 1200-2000 meters high and also strikes S 20° W-N 20° E. According to Yamasaki even the Tokansan with its altitude of 2830 meters, from which diorite rubble is washed down, is encased by Tertiary rocks.

In the west, this high Tertiary zone is followed by a Tertiary hilly region--in the northern part it is separated by a longitudinal valley with Chinese settlements--which continues to boast elevations up to 830 meters. The entire Tertiary land of the west side consists of clastic rock formations and is folded in the direction of strike mentioned. Fossils that could be identified have not been found here, nor on the south and east side.

Westward the Tertiary region is followed by the slopes leading down towards the coast; the formations are attributed to the Quaternary. South of Tainan reef, mountains of coral

limestones are included in it; the highest of them is the Takao-san (323 meters) on the coast near Takao. Farther north these features are not found. The large lowland area that claims more than one third of the total width of the island in some places between the twenty-third and the twenty-fourth parallel North, is a stepped plateau. It consists mainly of gravel deposits thought to be Diluvian in date and reaches a height up to 500 meters. [972]

The most intensive explorations have been carried on in the Tertiary region of the northern part of Formosa. For here coal seams near the popular port of Kilung have aroused industrial speculation and, besides, the occurrence of marine fossils in clayey incalcations have been of interest. Yamaschita found eight coal seams in the complex o layers which was in the main composed of coarse sandstones and shales; he was able to distinguish two anticlines and three synclines, all oriented from west to east.

The interpolated layers of limestone are up to ten feet thick. The fossils contained in them have been studied by Newton and Holland, who stress the Lithothamnium rosenber Martin which occurs also in the Miocene of Timor and on the island of Ischigaki. Other fossils did not refute this dating. Yoschiwara supplements these studies by his own observations near the east coast. As I stated previously, he found the boundary of the Tertiary south of Giran, and believes that everything north of this latitude dates of the Tertiary and that the mountains are composed of folds striking west-east.

On the other hand, Yamasaki and reports in the Geology of Japan speak of a

southwestern-northeastern direction of strike in this part of the island, and of a turn of the Kali mountain chain in the same direction.

In the very north, the structure of Formosa includes a group of volcanoes which have previously attracted attention. The mountains are composed of andesites and their tuffs; they are located on both sides of the lower course of the northern Tamsui river, mainly in the north. They reach altitudes of 800-1100 meters and exhibit some solfataric action. A connection with the other group of volcanoes cannot be recognized.

The relief of the bottom of the ocean around Formosa is only superficially known since soundings have been limited. On the west coast a good deal of new land has appeared, and here the bottom slants down in a straight line. The flat bottom that has a consistent depth of fifty meters extends furthest just off the delta of the Dakusui-kei. Shallow water is found from here to the Chinese coast. The Pescadores Islands, basalt formations, rise from it and are separated from Formosa by a somewhat [973] deeper channel, although it does not exceed 200 meters. The submarine slope in the east is more pronounced and soon soundings for 1500 meters and 1900 meters did not reach bottom. But the few depths that could be charted on this side indicate that up to the 200 meter line this zone has in some places the fairly considerable width of 20 or thirty kilometers; this is especially true of the region of the steepest descent between Schiyō and Soō and from there to Cape Santiau.

Conclusions about the Relation of the Riukiu Curve to Formosa.

1. According to the available information, the basic structure of Formosa seems to consist of two parts:
   a. The Taiwan Mountains. On the whole, their various mountain units, and thei inner strata (with the exception of the section of the watershed) strike N 20° S-S 20° W. These mountains are composed mainly of rocks defined as Archean crystalline schists and a complex of layers predominantly of argillaceous schists thought to date from the Paleozoic. The dip is westward. Not until a western point is reached does the cross-section show a change from anticline to syncline and reveals a structure of great folds.
   b. Mountains extending from Cape Dom-kaku by way of the Setsu to the Kalisan; the strike is E-W and the rocks have been recognized as being of the type of the Paleozoic Chichibu layers. The dip is northerly.
2. The Tertiary mantle corresponds to these two directions of strike. South of the parallel of the Dom-kaku in the Tertiary formations of the west and east side, the strike is always parallel to the structure of the Taiwan Mountains. On the peninsula in the south, the formation seems to be less steep as it lies over the ended-up bed of argillaceous schist. North of the Dom-kaku line Yoshiwara and his assistants observed a strike that was W-E in all instances, but other men claim

that they also found a strike SW-NE.

3. The directions of dip in the old formations of the Taiwan Mts. point towards a thrust ESE whereas in the Dom-kaku chain the thrust was from north to south.
4. The Dom-kaku chain is located in the continuation of the outer curve of the Riukiu Islands and is a component part of it. This curve [974] is broken in the Sakischima group neighboring Formosa and is disturbed in the directions of strike of the inner structure, although the curved line is maintained. The Taiwan Mountains disappear in southern Formosa. There are no signs of a continuation towards the south. But the mountains are so massive that they must be thought of as the lonely remnant of a larger curved folded mountain ridge which, by analogy with all other curved mountain formations of eastern Asia, faced the Pacific with its outer side.
5. The volcanic inner curve of the Ryukyu islands continues westward in the ridge of the Dom-kaku chain. Here the Agincourt Islands and the volcanic group in the west of Kilung belong to it. In back of the Taiwan Mountains the only volcanic formations are the Pescadores; their main axis is again oriented NNE or more accurately N 15° E.
6. The Ryukyu Curve and the fragment of the curve contained in the Taiwan mountains have one characteristic in common, namely that on the outer side a zone of tertiary sediments is piedmont to it. That means that in both cases the basic

structures on the front side are found at a relatively great depth. But it is not possible to decide whether these are areas of marine abrasion on which debris washed down from the mountains was deposited and gradual subsidence went hand in hand with it, or whether the down warping was along fault lines. The latter is more probably on Formosa because volcanic formations are found in the Taitō Mts. In the case of the Ryukyu Curve, they have been observed only in the old volcano of Nosoko on the island of Ischigaki.

7. Later displacements have been of the same type in both curves. The Tertiary formations must have risen at least to their present height above sea level, and erosion must have given them a shape approximating that which they exhibit nowadays. Subsidence followed and the corals formed the reefs at that time, which later were exposed when a renewed vertical shift followed.
8. The Ryukyu Curve and the Taiwan curve fragment are distinguished from the curved formations of the mainland by their concordance of the inner structure and lines of down warping in the parts corresponding to the meridional component. [975] Exactly like the Japanese curve they appear, therefore, as mountains in which the outer shape bears a causative relation to the folding thrust from the inside to the outside. But as a rule only more or less curved tension faults could be recognized with some certainty and they were discordant to the directions of strike of the inner structure.

9. The idea that the structure and tectonic lines of the southern Kiuschiu remained without any influence on the shaping of the Ryukyu Curve but that the later processes of dislocation in its northern part exerted considerable influence on the outer appearance of the southern Kiuschiu, finds its analogy in the relation of the Ryukyu Curve to Formosa. For in the Taiwan Mts. no traces of morphological influence by the processes responsible for the tectonic lines of the Kiuschiu can be recognized. On the other hand, the dislocations which produced the final shape of the Taiwan Mts. and found their most characteristic expression in the delimitation of the old mountain stock by the straight Taitō valley have also broken up the Ryukyu Curve; they separated the Dom-kaku mountain section on Formosa from it and probably caused the disturbances which occurred only in the Sakischima group of the Ryukyu Curve.
10. Thus the factual material increases which allows us to make some conclusions as to a number of the manifold curved mountain formations of eastern Asia north of the 22nd parallel (i. e., with the exception of the Annamite Curve): the normal structure of the parts of every curve that belonged to the equatorial component was completed before the structure of the parts located in the meridional component. When the two were joined to constitute a curve, tectonic processes were active and gave the normal shape to the meridional unit by means

of later longitudinal downthrusts and disruptive longitudinal faults. They also had effect on the equatorial unit of the curve that originally was adjacent in the north and as abnormal dislocations they resulted in unusual transverse members and transversal dismemberment.

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